FUNCTIONAL OUTCOME OF INTERLOCKING INTRAMEDULLARY NAILING OF FRACTURE SHAFT OF HUMERUS - A PROSPECTIVE STUDY

Dissertation submitted to

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CERTIFICATE

This is to certify that DR.V.THIRUNARAYANAN, postgraduate student (2006-2009) in the department of orthopaedics, Government Kilpauk Medical College, Chennai has done his dissertation on“ ***FUNCTIONAL OUTCOME OF INTERLOCKING INTRAMEDULLARY NAILING OF FRACTURE SHAFT OF HUMERUS- APROSPECTIVE STUDY”*** under my guidance and supervision in partial fulfillment of the regulation laid down by the **THE TAMILNADU DR.M.G.R. MEDICAL UNIVERSITY,** Chennai for M.S.(Orthopaedics) degree examination to be held on March 2009 **.**

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DECLARATION

I , DR.V.THIRUNARAYANAN, solemnly declare that dissertation titled ***FUNCTIONAL OUTCOME OF INTERLOCKING INTRAMEDULLARY NAILING OF FRACTURE SHAFT OF HUMERUS*** is a bonafide work done by me , at government Kilpauk Medical College between 2006-2009, under the guidance and supervision of my respected unit chief **Prof.Dr.K.SANKARALINGAM D.Ortho., M.S.Ortho.,DNB Ortho.**

This dissertation is submitted to THE TAMILNADU DR.M.G.R. MEDICAL UNIVERSITY, towards partial fulfillment of regulation for the award of **M.S. DEGREE BRANCH- II** in Orthopaedic surgery.

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CONTENTS

INTRODUCTION

Fractures of the shaft of humerus account for approximately 3-5% of all fractures treated. Historically humeral shaft fractures have been classified by fracture location, fracture pattern, associated soft tissue injuries and quality of bone. This fracture has been treated by closed reduction & cast application with/without cast bracing and open reduction & internal fixation using dynamic compression plate. Many authors have documented the general good outcome that occurs after compression plate fixation, which is still considered the gold standard for operative treatment of acute humeral shaft fractures. Though plate fixation has given high rates of union, it involves extensive soft tissue stripping, potential injury to radial nerve and poor fixation in osteoporotic bone. Later flexible nails of many varieties were used. The advantages of intramedullary nailing are minimal surgical exposure, better biological fixation, minimal disturbances of soft tissues and early mobilization of neighboring joints.

The technique of interlocking nailing represents the newer approach of the treatment of humeral fractures. Interlocking nailing also avoids complications like lack of rotational control, migration of nail and requirement of supplementary bracing. The Seidel nail was the first nail to be tested clinically. Eventually several nail systems evolved.

Indications for Surgical Management

There are certain situations in which treatment by primary operative fixation of fractures may have to be considered. These are

1) Patients whom satisfactory alignment cannot be achieved or maintained by conservative method.
2) Patients with multiple injuries in whom early mobilization is desirable
3) Bilateral humeral shaft fractures
4) Segmental fractures
5) Fractures associated with vascular deficits
6) Holstein and Lewis type of fracture associated with Radial Nerve Palsy
7) Fractures associated with ipsilateral ulna & radius fractures
8) Pathological fractures
9) Radial nerve palsy following closed reduction

Various methods of osteosynthesis have been evolved through the years to achieve union of fracture shaft of humerus

Available treatment options

1. Thoraco brachial immobilization
2. Closed reduction and hanging arm cast
3. Body arm bandage
4. functional cast bracing

5. Closed reduction and U-slab splinting
6. Open reduction and internal fixaton with
    - Plate osteosynthesis
    - Intramedullary nailing
    - multiple nails
    - flexible nails
7. Closed reduction and internal fixation with
    - Antegrade Intramedullary interlocking nailing
    - Retrograde Intramedullary interlocking nailing

6. External Fixator application

AIM OF THE STUDY

The aim is to prospectively study the “functional outcome of interlocking intramedullary nailing in acute fractures and non-union of the diaphysis of humerus” , at the Department of Orthopaedics and Traumatology , Government Kilpauk Medical College, Chennai.

Review of Literature

Diaphyseal fractures of the humerus accounts for 3-5% of all fractures . Various treatment modalities are evolving over the period of time. Historically closed method of treatment have centred around one of the two principles:

1. Thoraco brachial immobilization
2. Dependency traction

Thoraco brachial immobilization involved use of body as a splint. This was achieved by using body strapping or by shoulder arm spica application. This method of treatment was no5t reliable for maintaining alignment and promotion of bone healing.

Caldwell promoted Hanging arm cast as a treatment option for management of Humeral shaft fractures. They are stipulated to weigh less than 2 lbs ., in order to avoid fracture distraction. These casts are provided with series of loops that are used to correct angular deformities.

U- slabs or Co-aptation splints were devised based on dependency traction. These are effective methods of treatment but functionally inferior to bracing.

Treatment of humeral shaft fractures was revolutionized by the introduction of functional bracing by Sarmiento. This is a fracture treatment orthoses made up of light-weight plastic brace fitted with

Velcro straps. This has provided excellent long term results with 100% union rate with minimal complications of malalignment, infections, and iatrogenic nerve injury.

Various studies have shown bracing to be a much superior fracture treatment in an otherwise normal individual. Operative intervention was necessary in patients with malalignment.

Klenerman et al and Balfour et al found in various studies that a valgus angulation of more than 15 degrees unacceptable cosmetically though they found that this was not having any functional disability.

Broad dynamic compression plating was promoted by AO/ASIF for fracture stabilization. They noted complication rates of 7% hardware failure,6% infection and 5% chances of iatrogenic nerve palsy. This is still considered gold standard in treatment of humeral diaphyseal fractures.

Kuntscher proposed Intramedullary nailing for management of diaphyseal fractures of femur, the Tibia and Humerus during world war II. This was later promoted by Maatz.

Flexible nails in multiple numbers can be inserted into the humerus from both antegrade and retrograde entry portal. The nails in use are

- Ender’s nail
- Hackethal nail

- Rush nail

Though they are found to have good prognostic outcome higher complication rates of non-union, nail cut through into articular surface are always to be kept in mind.

Interlocking intramedullary nailing was the obvious sequel for this and the first nail introduced was the Seidel's nail. Here the distal locking was achieved by expandable fins, which are opened within the barrel. This fell into disrepute due to the complications associated with flange failure.

Newer developments include the Marchetti Vincenzi nail, the Russell Taylor nail, Synthes design which have lesser complication rates of implant failure, iatrogenic radial N palsy and infection than plate osteosynthesis.

Recently interlocking nailing has been promoted in the Retrograde insertion to prevent shoulder impingement syndrome and is technically more demanding.

Inter locking nailing has been found useful in treatment of non union of fracture of the humerus and pathological fractures of the humerus.

ANATOMY

The **humerus** is the longest and largest bone of the upper extremity; it is divisible into a **long tubular diaphysis a globular proximal metaphysic and a flattened distal metaphysis.**

Upper Extremity—The upper extremity consists of a large rounded *head* joined to the body by a constricted portion called the **neck,** and two eminences, the **greater** and **lesser tubercles.**

The Head (*caput humeri*)—The head, nearly hemispherical in form, is directed upward, medialward, and a little backward, and articulates with the glenoid cavity of the scapula. The circumference of its articular surface is slightly constricted and is termed the **anatomical neck,** in contradistinction to a constriction below the tubercles called the **surgical neck** which is frequently the seat of fracture. Fracture of the anatomical neck rarely occurs.

The Body or Shaft (*corpus humeri*).—The body is almost cylindrical in the upper half of its extent, prismatic and flattened below, and has three borders and three surfaces.

Borders.—The **anterior border** runs from the front of the greater tubercle above to the coronoid fossa below, separating the antero-medial from the antero-lateral surface. Its upper part is a prominent ridge, the crest of the greater tubercle; it serves for the insertion of the tendon of

the Pectoralis major. About its center it forms the anterior boundary of the deltoid tuberosity; below, it is smooth and rounded, affording attachment to the Brachialis.

The **lateral border** runs from the back part of the greater tubercle to the lateral epicondyle, and separates the anterolateral from the posterior surface. Its upper half is rounded and indistinctly marked, serving for the attachment of the lower part of the insertion of the Teres minor, and below this giving origin to the lateral head of the Triceps brachii; its center is traversed by a broad but shallow oblique depression, the **radial sulcus** (*musculospiral groove*). Its lower part forms a prominent, rough margin, a little curved from behind forward, the **lateral supracondylar ridge,** which presents an anterior lip for the origin of the Brachioradialis above, and Extensor carpi radialis longus below, a posterior lip for the Triceps brachii, and an intermediate ridge for the attachment of the lateral intermuscular septum.

The **medial border** extends from the lesser tubercle to the medial epicondyle. Its upper third consists of a prominent ridge, the **crest of the lesser tubercle,** which gives insertion to the tendon of the Teres major. About its center is a slight impression for the insertion of the Coracobrachialis, and just below this is the entrance of the nutrient canal, directed downward; sometimes there is a second nutrient canal at the commencement of the radial sulcus. The inferior third of this border is

raised into a slight ridge, the **medial supracondylar ridge,** which becomes very prominent below; it presents an anterior lip for the origins of the Brachialis and Pronator teres, a posterior lip for the medial head of the Triceps brachii, and an intermediate ridge for the attachment of the medial intermuscular septum.

Surfaces —The **antero-lateral surface** is directed lateralward above, where it is smooth, rounded, and covered by the Deltoideus; forward and lateralward below, where it is slightly concave from above downward, and gives origin to part of the Brachialis. About the middle of this surface is a rough, triangular elevation, the **deltoid tuberosity** for the insertion of the Deltoideus; below this is the **radial sulcus,** directed obliquely from behind, forward, and downward, and transmitting the radial nerve and profunda artery.

The **antero-medial surface,** less extensive than the antero-lateral, is directed medialward above, forward and medialward below; its upper part is narrow, and forms the floor of the intertubercular groove which gives insertion to the tendon of the Latissimus dorsi; its middle part is slightly rough for the attachment of some of the fibers of the tendon of insertion of the Coracobrachialis; its lower part is smooth, concave from above downward, and gives origin to the Brachialis.

The **posterior surface** appears somewhat twisted, so that its upper part is directed a little medialward, its lower part backward and a little

lateralward. Nearly the whole of this surface is covered by the lateral and medial heads of the Triceps brachii, the former arising above, the latter below the radial sulcus.

The Lower Extremity.—The lower extremity is flattened from before backward, and curved slightly forward; it ends below in a broad, articular surface, which is divided into two parts by a slight ridge. Projecting on either side are the lateral and medial epicondyles. The **articular surface** extends a little lower than the epicondyles, and is curved slightly forward; its medial extremity occupies a lower level than the lateral. The lateral portion of this surface consists of a smooth, rounded eminence, named the **capitulum of the humerus;** it articulates with the cup-shaped depression on the head of the radius, and is limited to the front and lower part of the bone. On the medial side of this eminence is a shallow groove, in which is received the medial margin of the head of the radius. Above the front part of the capitulum is a slight depression, the **radial fossa,** which receives the anterior border of the head of the radius, when the forearm is flexed. The medial portion of the articular surface is named the **trochlea,** and presents a deep depression between two well-marked borders; it is convex from before backward, concave from side to side, and occupies the anterior, lower, and posterior parts of the extremity. The lateral border separates it from the groove which articulates with the margin of the head of the radius. The medial border is

thicker, of greater length, and consequently more prominent, than the lateral. The grooved portion of the articular surface fits accurately within the semilunar notch of the ulna; it is broader and deeper on the posterior than on the anterior aspect of the bone, and is inclined obliquely downward and forward toward the medial side. Above the front part of the trochlea is a small depression, the **coronoid fossa,** which receives the coronoid process of the ulna during flexion of the forearm. Above the back part of the trochlea is a deep triangular depression, the **olecranon fossa,** in which the summit of the olecranon is received in extension of the forearm. These fossae are separated from one another by a thin, transparent lamina of bone, which is sometimes perforated by a **supratrochlear foramen;** they are lined in the fresh state by the synovial membrane of the elbow-joint, and their margins afford attachment to the anterior and posterior ligaments of this articulation.

Structure.—The extremities consist of cancellous tissue, covered with a thin, compact layer the body is composed of a cylinder of compact tissue, thicker at the center than toward the extremities, and contains a large medullary canal which extends along its whole length.

Neuro Vascular Relations:

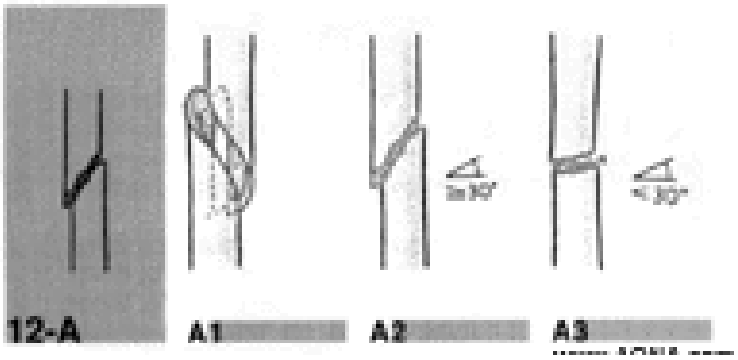
Three important neurovascular bundles flank the humerus in its anatomical relations. The axillary nerve runs around the proximal

metaphysic of the humerus supplying the deltoid. It is about on an average 4.56 cms from the lateral edge of acromian. The Radial nerve accompanied byProfunda Brachial vessels runs around the posterior aspect of humerus in the Radial groove flanked by the medial and lateral head of Triceps. This structure is important in the exposure of humerus by Posterior approach. Occasionally it may get entrapped in the fracture resulting in Radial nerve palsy. The Brachial vessels , the Median nerve, the Ulnar nerve and the Medial cutaneous nerve of forearm run in the space between biceps and brachialis.

APPLIED SURGICAL ANATOMY

- The entry point of humerus inter locking nail is very close to the passage of bicipital tendon and if protrudes out it may irritate the tendon.
- While exposing the entry point we have to carefully expose the rotator cuff which has to be properly repaired.
- The entry point is intra articular and may lead to shoulder stiffness.
- The axillary nerve runs at a distance of around 4.56 cms from the angle of acromian. It may be injured while applying the proximal locking.
- The radial nerve which runs very close to the bone in the middle third of humerus may be injured by the fracture, during reduction or during surgical exposure.
- The canal ends at around 3cms above the olecranon fossa.
- The Brachialis has a dual nerve supply by the musculocutaneous and the Radial nerve. This fact is used while developing the fracture in anterolateral approach.

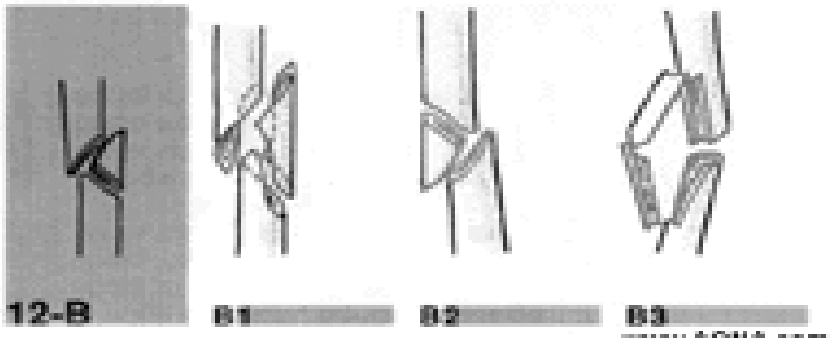
AO/ASIF CLASSIFICATION OF FRACTURE SHAFT OF HUMERUS.



A1 Simple fracture, spiral
.1 proximal zone
.2 middle zone
.3 distal zone

A2 Simple fracture, oblique(> or = 30°)
.1 proximal zone
.2 middle zone
.3 distal zone

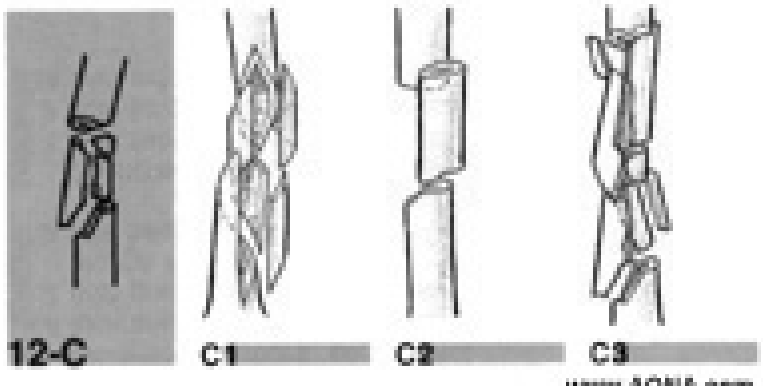
A3 Simple fracture, transverse (< 30°:)
.1 proximal zone
.2 middle zone
.3 distal zone



B1 Wedge fracture, spiral wedge
1 proximal zone
2 middle zone
3 distal zone

B2 Wedge fracture, bending wedge
1 proximal zone
2 middle zone
3 distal zone

B3 Wedge fracture, fragmented wedge
1 proximal zone
2 middle zone
3 distal zone



C1 Complex fracture, spiral
1 with two intermediate fragments
2 with three intermediate fragments
3 with more than three intermediate fragments

C2 Complex fracture, segmental
1 with one intermediate segmental fragment
2 with one intermediate segmental and additional wedge fragment(s)
3 with two intermediate segmental fragments

C3 Complex fracture, irregular
1 with two or three intermediate fragments
2 with limited shattering (< 4 cm)
3 with extensive shattering (> or = 4 cm)

BIOMECHANICS OF INTRAMEDULLARY REAMING

VASCULAR DISTURBANCES FOLL. FRACTURES OF LONG BONES

BLOOD SUPPLY OF LONG BONES

In general all long bones have separate ,anastamotic metaphyseal and diaphyseal blood supplies. The diaphysis is supplised primarily by one or more nutrient arteries, and an extraosseous soft tissue sleeve provide an abundant source of periosteal vessels that are concentrated around fascial attachments.

Two nutrient vessels supply the humerus. The humerus also has an abundant , circumferential extraosseous soft tissue sleeve. Rhinelander recognized the normal blood flow through the diaphyseal cortex of long bone as centrifugal, flowing through medulla to periosteum. He described three functional components of bone blood supply.

a. Afferent vascular system carries nutrients and oxygen
b. Efferent vascular system that carries the waste away from the bone
c. Intermediate vascular system , which functions as the connecting link between the afferent and efferent systems within cortical bone

Afferent vascular system has 3 components

- **Nutrient artery system**
- **Metaphyseal arterioles**
- **Periosteal vessels**

The principal nutrient artery, traverses the cortex of long bones , they enter the medullary cavity and divide into ascending and descending branches . They give rise to radially arranged lateral conduits which enter the endosteal surface of diaphyseal cortex and branch of into short segments of ascending and descending para endosteal vessels that parallel the longitudinal axis of the long bone. The lateral conduit arteries and arterioles divides into ascending and descending bifurcations after entering into the surrounding osteon.

Periosteal arterioles supplies the outer thirds of the cortex. Nutrient artery and periosteal arterioles are able to supplement each other if one of them is compromised.

METAPHYSEAL CIRCULATION

Metaphyseal circulation occurs through concentric arrangement of metaphyseal arteries which enter near the fascial attachments. Arteries which supply the joint may also give branches. They form an arcade which supplies the whole of metaphysic. These arteries give anastamotic channels to the nutrient artery thereby supplementing the cortical supply.

FRACTURE SITE REVASCULARISATION

Fracture site revascularization is possible by a number of ways, periosteal, edosteal or intracortical revascularization may occur. In addition a new and transitory extra osseous blood supply may be derived

from the soft tissues surrounding the fracture , it serves to nourish the periosteal callus and detached fracture fragments.

Intramedullary reaming causes destruction of the contents of the marrow Cavity (Blood vessels and marrow). The medullary canal is irregular in both longitudinal and cross sections. For a stable intramedullary fixation a firm fit is needed. The process of reaming produces a larger contact area between the nail and bone thereby increases the stability of fixation. Reaming allows insertion of larger diameter , stronger nail and reaming can stimulate fracture healing by providing a source of autologous bone graft from the reamed particles at the fracture site.

EFFECTS OF REAMING ON BONE STRENGTH

Reaming allows insertion of a larger diameter nail with a larger surface area and a more secure fixation. Fortunately, reaming removes only the endosteal bone and the bone strength is not compromised.

REAMING TECHNIQUE

Passage of a tight reamer in a tight medullary canal acts as a piston in a cylinder. Heat and hydraulic pressure are produced that destroys the endosteal surface and marrow contents. The amount of pressure that develops depends on the flow rate of medullary contents out of medullary cavity. Good reaming technique facilitates passage of the medullary

contents out of the canal, prevents cortical temperature increase, and avoid significant increase in the medullary pressure.

To lower the pressure and temperature associated with reaming,

- Sharp cutting flutes must be used
- Reamer heads should be designed to propagate, limit the amount of debris and disperse a large amount of medullary fluids. Long deep flutes facilitate passage of medullary contents. Flow rate is directly proportional while the increase in intramedullary pressure is inversely proportional to the diameter of the reamer and the diameter of the driver shaft.
- Axial advancement should be slow with the reamer rotating at full speed. This reduces cortical necrosis and crack propagation. When any resistance is encountered reaming should be stopped, as the reamer advances the fracture site, the advancement and rotation speed are reduced to ensure that the fracture fragments are anatomically aligned to prevent eccentric reaming.
- A distal vent can be used to remove the cavity pressure. However the viscosity of the medullary contents determines their ability to pass through the hole.

CONSEQUENCES OF REAMING

High intramedullary pressure forces the medullary contents into general ciculation which can lead to pulmonary microembolism and circulatory dysfunction.

Medullary contents can get entrapped in the cortical wall which can slow down the revascularization of the cortical bone and disturb healing.

PRINCIPLES OF FRCTURE TREATMENT BY INTERLOCKING NAILING

Interlocking nail is a safe and effective means of fracture fixation. The early mobilization for the neighboring soft tissues and joints is a proof of the stability of this type of fixation.

Basic concepts with interlocking nail of humerus

a. It can be used to fix any fracture within 2 cms distal to the surgical neck of humerus and 3 cms proximal to the proximal tip of olecranon fossa.
b. Close nailing is the more biological method of fixation.
c. Bony union is the primary objective of surgical procedure and is no way a substitute for bony union
d. Image intensifier control is mandatory
e. Adequate nail sizes are proper instrumentation is necessary
f. Intramedullary nailing is complemented with reaming.

UNREAMED NAILS

Rush nails, Enders nails, Hackethal nails Unreamed humeral nail AO(synthes)

ADVANTAGES

- Lesser operating time
- Lesser disruption of endosteal blood supply
- Lesser infection rate

- Lesser chances of disruption of fragment comminution

DISADVANTAGES

- Smaller size nail only can be used

REAMED NAILS

Cannulated nail system

ADVANTAGES

- Allows use of larger size implant
- Allows better nail bone interface
- Reamed material has osteogenic potential
- Morcelised bone fragments promote bony union

DISADVATAGES

- More chances of splintering
- Loss of endosteal blood supply
- Increase risk of fat embolism
- Higher infection rate
- Ned for cannulated reamers

STATIC LOCKING AND BRIDGING FIXATION

Screw insertion at the two ends of humerus nail provides rotational stability .this is very important as the stresses in humerus is more of rotational than axial. Static locking achieves a bridging fixation. In the bridging fixation the implant extends across the fracture site and is fixed

to the major proximal and distal bone fragments by locking screws located away from the fracture site. Static locking is effective in treating fractures with severe comminution, delicate soft tissue cover, long oblique or spiral fractures. In these situations it is undesirable to open the fracture site and devascularise the fragments.

NAIL LENGTH AND WORKING LENGTH

In working with interlocking nailing, three lengths of the nail becomes significant

a. Total nail length
b. Length of nail bone contact
c. Working length

Total length is purely anatomical. Too long a nail may protrude at the point of insertion.The length of nail bone contact reflects the total surface area of contact between the nail and bone. This may provide for the rigidity of nail fixation.Working length is the most crucial factor in determining the success of fixation. It is defined as the length of the nail spanning the fracture from the distal most of the proximal locking and the proximal most of the distal locking. This defines the length of bone carrying the load across the fracture. The bending stiffness of a nail is inversely proportional to the square of its working length. The torsional stiffness is inversely proportional to the working length, the more shorter the nail the stronger the fixation. To avoid potential non unions nail

dynamization was done by removing either the proximal or distal screws. Removal of the screws would allow the nail to glide that creates micro motion at fracture site that augments in the quicker union.

SCREW STRENGTH

The shape of the thread at their base determines their stress concentrating factor, with a sharp base likely to lead to screw breakage than a rounded base. The strength of the screw is dependent on the root diameter. A small increase in the diameter increases the strength largely. The pullout strength is dependent on the outer diameter. Larger outer diameter can engage more bone and effect a stronger fixation.

FRACTURE HEALING FOLL. INTRAMEDULLARY NAILING

The healing pattern following intramedullary nailing depends upon type of fracture and degree of stabilization. In simple fractures without much soft tissue damage reaming and Intra medullary nailing is followed by circulatory deficiencies, that extend to the peripheral parts of the cortical bone, at the fracture site the formation of external callus is not impeded. In more complex fractures, the trauma itself provides interruption of the medullary circulation of the intermediate fragments, while the periosteal circulation is generally maintained, therefore reaming process causes little additional damage, fracture heals by callus formation at the peripheral perfused cortical bone which grows over the fracture gap.

TREATMENT PROTOCOL

Fractures of humeral diaphysis are commonly associated with other systemic injuries viz, thoracic injuries, maxillofacial injuries, and brachial plexus injury. Any neurovascular involvement and other life threatening injuries must be immediately looked into and treated. There are certain situations in which treatment by primary operative fixation of fractures may have to be considered. These are Patients whom satisfactory alignment cannot be achieved or maintained by conservative method.

- Non- compliance
- Patients with multiple injuries in whom early mobilization is desirable
- Bilateral humeral shaft fractures
- Segmental fractures
- Fractures associated with vascular deficits
- Holstein and Lewis type of fracture associated with Radial Nerve Palsy
- Fractures associated with ipsilateral ulna & radius fractures
- Pathological fractures
- Radial nerve palsy following closed reduction

PREOPERATIVE MANAGEMENT

Once the patient is systemically stabilized the patient is processed for surgery. Till the time of surgery a U-slab is applied as a temporary method. The nail size is measured with the full length x-ray from tip of greater tuberosity to 3cms above the proximal tip of olecranon fossa. Clinically it is measured by subtracting 5 cms from the tip of acromian to the lateral epicondyle of humerus. The best method is by a scanogram where the nail of appropriate length is tied to the patient and x-ray is taken.

INSTRUMENTATION

In spite of pre-operative planning it is mandatory to keep all sized nails and also to keep dynamic compression plating also autoclaved. In our study we have used 20 sharma surgical nail. All instrumentation necessary for the nailing must be kept available. Image intensifier is also made available.

POST OPERATIVE PROTOCOL

Supported mobilization exercise of shoulder from Day-I

Wound inspection on Day-II

Suture removal on 12^{th} day

Pendular motion excercise , supported and active abduction exercise, circumduction exercise, flexion exercise of elbow

Progressive increase in weight lifting

Serial x-rays in monthly intervals in two perpendicular planes to look for fracture union.

IMPLANT DESIGN

Humerus interlocking nail used by us was made of stainless steel 316L. They are available in diameters of 6.0mm that are non cannulated solid nails and the 7.0mm cannulated nails. They can be inserted over 2.4 mm thick guide wire.The nails are available in various lengths starting from 160 mm onwards at increments of 10mm . the distal end is blunt and beveled to allow easy negotiation of the nail. The nails have an internal thread in the proximal end to accommodate the locking nut in the jig. The proximal end is broadened to accommodate thicker screws. Three circular static slots are provided for locking. The proximal locking is provided from lateral to medial direction. The distal locking for the 6.0mm solid nails are 2 in number and both are static. The distal locking for the 7.0mm cannulated nails are 2 in number the proximal being dynamic and the distal static. The distal locking are in the anteroposterior direction.The locking screws are self tapping cortical screws. The distal locking can be done both through the jig and image intensifier.

SURGICAL TECHNIQUE

ANTEGRADE HUMERUS NAILING BY CLOSED METHOD

The whole of the upper limb and axilla is prepared. The patient is maintained under general anesthesia or interscalene block for the procedure. The patient is placed in supine position with a sand bag under the affected shoulder for better exposure of the entry point, the whole arm is painted and draped in order to keep the limb free.

ENTRY POINT

Through the image intensifier the entry point which is just medial to the greater tuberosity and in the area at junction between the articular surface of the head and greater tuberosity is marked with a 15 mm long 2.00 mm thick K- wire. After marking the entry point the K-wire is pushed 3-4mm into the humerus under image intensifier control . An incision is made that extends around 2 cms with the k- wire as centre. This exposes the multi-pennate deltoid muscle, which is split along its fibres , and it must be kept in mind that the axillary nerve is on an average 4.56 cms below the angle of acromian. This expose the white glistening rotator cuff , which has to be split at the tendon of supraspinatous just medial to its insertion at the greater tuberosity. This being vascular heals better. The entry point reamer is used and through the k-wire the entry point is enlarged. The k-wire is removed keeping the

entry point reamer in situ. The k-wire is now exchanged with the 45 cms long guide wire, the entry point reamer is removed keeping the guide wire in the humerus. This method prevented any false passage of the guide wire and quick and easy. With image intensifier the guide wire is passed through the distal fragment.

NAIL INSERTION

Progressive reaming is done upto 1mm more than the proposed size of the cannulated nail. The nail is mounted on the jig, and inserted through the guide wire. For non cannulated solid nails after mounting the nail onto the jig it is inserted through the entry point and negotiated carefully across the fracture site under the control of image intensifier. The nail size should be carefully selected because over size nail may end up splintering the distal fragment.the nail is pushed to a level where the nail is not protruding out through the articular surface of the proximal humerus.

DISTAL LOCKING

Two sizes of nails were used which are the 6mm solid nails and the 7mm cannulated nails. The distal locking in the 6mm nails are the self tapping 3.5mm locking screws for which 2.5mm drill bits are used. The distal locking for the 7mm cannulated nail was 4.5 mm self tapping locking screws for which 3.00mm drillbits were used. The distal locking are antero-posterior locking. Under image guidance a stab incision is

made at the anterior aspect of forearm , the bicep and brachialis is split to expose the surface of thew bone. Under image guidance the appropriate drill bit is used and the distal screws are inserted. Though the distal locking jigs are available it did not prove to be successful most of the times.

PROXIMAL LOCKING

This is done using the proximal jig that is mounted with the nail. There are 3 slots for proximal locking. 4.5 mm self tapping screws for which 3.0 mm drill bits are used. Care must be used to avoid the axillary nerve. The proximal locking are in the medio-lateral plane.

OPEN REDUCTION OF FRACTURES

This technique was used for fixing old fractures and fracture nonunion. All the steps were essentially the same but for the following aspect.

EXPOSURE OF FRACTURE SITE

Fracture site is exposed by anterolateral approach. Skin incision is made in the groove between the prominences of biceps brachii and deltoid. Cephalic vein is identified and ligated. Plane is created between the muscle bulk of biceps and deltoid. Brachialis is split in the middle to expose the fracture site. Fracture site is exposed and freshened. Bone grafting may be placed to promote fracture union. Other steps are similar to closed nailing.

MATERIALS AND METHODS

This is a prospective study of 20 Humeral diaphyseal fractures treated by Interlocking intramedullary nailing conducted for a period of 20 months from March 2007 to November 2008 at the Department of Orthopaedics, Government Kilpauk Medical College Hospital .

INCLUSION CRITERIA

- Acute shaft of humerus fractures
- Fracture Non-union
- 2cm below surgical neck to 3 cm above olecranon fossa
- Age above 18 years
- Pathological fractures
- Osteoporotic bone
- Polytrauma
- Neurovascular involvement
- Angulation more than 15 degrees after closed reduction
- Non compliance

EXCLUSION CRITERIA

1. Presence of open physis
2. compound fractures of more than Grade-I severity
3. fracture involving proximal 2cms and distal 3cms of the diaphysis

Initial management

All cases of acute fractures were immobilized in U-Slab till they were posted for surgery

Age distribution

Age	No of patients
21-30	6
31-40	2
41-50	5
51-60	4
>60	3

Mean age of 44.5 years

Sex distribution

Male	8
Female	12
total	20

Occupation

Laborer	6
Housewife	10
Student	2
Clerical worker	2

Side of injury

Right	12
Left	8
total	20

Fracture pattern AO Classification/Acute Fractures

Type A	10
Type B	4
Type C	0

NON-UNION- 6 CASES

CASE - I

Name	:Kamala
Age/Sex	:32/F
Mode of Injury	:RTA
Extremity	:Left
Associated Injury	:Fracture Both Bone Leg Left
AO Classification	:A
Time Interval between Injury and surgery	:8 days
Acute/Non-union	:Acute
Nail size	:7/240 mm
Post-op period	:Uneventful
Mobilisation started	:2nd day
Time of union	:8 weeks
Range of Movements	:Full
Complications	:Nil
Rodriguez-Merchan Criteria	:Excellent

CASE - II

Name	:Gopi
Age/Sex	:32/M
Mode of Injury	:RTA
Extremity	:Right
Associated Injury	:None
AO Classification	:B
Time Interval between Injury and surgery	:7 days
Acute/Non-union	:Acute
Nail size	:7/260 mm
Post-op period	:Uneventful
Mobilisation started	:2nd day
Time of union	:14 weeks
Range of Movements	:Full
Complications	:Nil
Rodriguez-Merchan Criteria	:Excellent

CASE - III

Name	:Manikandan
Age/Sex	:26/M
Mode of Injury	:RTA
Extremity	:Right
Associated Injury	:Liver Laceration
AO Classification	:
Time Interval between Injury and surgery	:3 Months
Acute/Non-union	:Non-union
Nail size	:7/280 mm
Post-op period	:Radial N. Neuropraxia
Mobilisation started	:2nd day
Time of union	:16 weeks
Range of Movements	:Full
Complications	:Radial N palsy recovered in 3mths
Rodriguez-Merchan Criteria	:Excellent

CASE - IV

Name	:Kalyani
Age/Sex	:65/F
Mode of Injury	:Fall
Extremity	:Right
Associated Injury	:
AO Classification	:
Time Interval between Injury and surgery	:6 months
Acute/Non-Union	:Non-union
Nail size	:7/200 mm
Post-op period	:Uneventful
Mobilisation started	:2nd day
Time of union	:16 weeks
Range of Movements	:Near Normal
Complications	:Nil
Rodriguez-Merchan Criteria	:Good

CASE - V

Name	:Thanikachalam
Age/Sex	:50/M
Mode of Injury	:RTA
Extremity	:Left
Associated Injury	:
AO Classification	:A
Time Interval between Injury and surgery	:15 days
Acute/Non-union	:Acute
Nail size	:6/260 mm
Post-op period	:Uneventful
Mobilisation started	:2nd day
Time of union	:16 weeks
Range of Movements	:Restricted
Complications	:Distal screw broken
Rodriguez-Merchan Criteria	:Fair

CASE - VI

Name	:Padma
Age/Sex	:32/F
Mode of Injury	:RTA
Extremity	:Right
Associated Injury	:
AO Classification	:A
Time Interval between Injury and surgery	:15 days
Acute/Non-union	:Acute
Nail size	:7/240 mm
Post-op period	:Uneventful
Mobilisation started	:2nd day
Time of union	:14 weeks
Range of Movements	:Full
Complications	:None
Rodriguez-Merchan Criteria	:Good

CASE - VII

Name	:Saraswathi
Age/Sex	: 42/F
Mode of Injury	:Fall
Extremity	:Right
Associated Injury	:None
AO Classification	:A
Time Interval between Injury and surgery	:12 days
Acute/Non-union	:Acute
Nail size	:7/200 mm
Post-op period	:Uneventful
Mobilisation started	:2nd day
Time of union	:Non-union
Range of Movements	:Restricted
Complications	:Non-union
Rodriguez-Merchan Criteria	:Fair

OBSERVATION

- Of all the cases acute fractures were 14 in number and fracture non-union were 6
- Female preponderance in the ratio of 12females : 8 males was noticed
- Road Traffic Accidents accounted for 14 of the 20 cases
- Right side preponderance was noticed
- AO/ASIF Type-A fractures were the most fracture pattern in our study
- Higher incidence was noticed in younger patients of age group 20-40 years
- In our study higher frequency was seen in housewives followed by manual laborers

OUTCOME

Of the twenty cases in our study which was carried out from march 2007 to November 2008 1 patient died and 2 lost follow up. All cases were followed upto a period of maximum of 20 months and a minimum of three months on an average of 10 months. Of the 2 cases that lost follow up 1 case was an acute fracture of the humeral diaphysis and the other was a case of non-union fracture shaft of humerus. The outcome was studied based on the Rodriguez-Merchan's scoring system.

FOLLOW UP

MAXIMUM	20 months
MINIMUM	3 months
AVERAGE	10 months

UNION

Of the 12 cases of acute fractures treated with interlocking intramedullary nailing of humerus 11 cases which came for follow up united, 1 case went in for non-union and 1 case which is in the 3rd month of follow up and ended up in distal screw breakage in the 6th week post-op, but is now showing signs of consolidation after application of functional bracing with the screws and nail in situ.

Of the 5 cases of non-union fracture shaft of humerus treated by interlocking nail 4 cases united and 1 case is in the 4th month of follow-up

and this particular case of non-union was treated by closed nailing and bone graft was not applied.

FRACTURE TYPE	FOLLOW UP	UNION
ACUTE FRACTURES	12	11
FRACTURE NON UNION	5	4

RATE OF UNION

	MINIMUM	MEAN	MAXIMUM
ACUTE FRACTURES	8 weeks	14.5weeks	16 weeks
NON UNION	16 weeks	20weeks	24 weeks

One of the acute fractures showed very fast rate of union and united in 8 weeks of follow-up. The average rate of union in acute fractures was around 14.5 weeks and the average rate of union for non-union are around 20 weeks.

COMPLICATIONS

Of the twelve cases of acute fracture 8 cases attained near normal range of movements compared to the normal side at an average follow up of 9 months. Proximal locking could not be done in 1 patient as the jig had become unsterile at the time of surgery, but the fracture had fully united in this patient. The proximal screws did not have purchase in the opposite cortex in 1 patient. 1 patient resorted to very early weight lifting against advice and ended up in the breakage of distal screws . He was managed by giving a functional brace with the nail and broken screws in situ.

In 3 cases the distal fracture site developed splinters during nail insertion and reaming. all the 3 fractures united fully with no evidence of the splinters.

NON-UNION	1 (5%)
DELAYED UNION	Nil
FAULTY PROXIMAL LOCKING	2 (10%)
SCREW BREAKAGE	1(5%)
INFECTION	NIL
SPLINTERING AT FRACTURE SITE	3(15%)
BENDING OF NAIL	NIL
PROXIMAL NAIL PROTRUSION	1(5%)

FUNCTIONAL DISABILITY

Of the 12 cases of acute fractures of humerus treated, 8 cases attained near range of movements in shoulder compared to the opposite side, 2 of the acute fracture cases who did not have full range of shoulder movement were operated 45 days after injury due to anaesthetic complications.1 case of acute fracture did not follow the post-op physiotherapy protocol that was advised. Of the cases of non-union 1 case achieved full range of movement, 1 case is in 3 months follow up and has nearly 75% of movements on the normal side.

It has been observed that proper aggressive post-operative physiotherapy protocol if followed full normal range of movements of shoulder is regained. 1 case of acute fracture which went in for non-union had moderate level of pain in the shoulder.

1 case who had a comminuted proximal ulnar fracture that was treated conservatively had moderate restriction of movements in the elbow.

Restriction of movements in shoulder	Acute	4
	nonunion	3
Restriction of movements in elbow		2
Significant pain in shoulder		3

Time interval of surgery

Maximum		6 months
Minimum		7 days
Average	acute	17.7days
	nonunion	4.5 months

Method of reduction

Open	6
Closed	14
Total	20

RODRIGUEZ MERCHAN CRITERIA

Rating	Elbow ROM	Shoulder ROM	Pain	Disability
Excellent	Extension 5 Flexion 130	Full ROM	None	None
Good	Extension 15 Flexion 120	<10% loss of total ROM	Occasional	Minimum
Fair	Extension 30 Flexion 110	10% to 30% loss	With activity	Moderate
Poor	Extension 40 Flexion 90	> 30% loss	Variable	severe

Shoulder

Excellent	42%
Good	25%
Fair	25%
Poor	8%

Elbow

Excellent	80%
Good	20%
fair	nil

DISCUSSION

The results of use of Interlocking nailing for Diaphyseal fractures of the humerus has been mixed in various studies with some studies showing good outcome and a few showing poor outcome. In some studies a significant number of patients do not return for follow-up once the limb is functional and useful. **Non-union and Functional disability** of the shoulder are the two most common problems faced in most patients postoperatively.

An average delay of 17 days was noted from the time of injury to the day of surgery which was the time delay in getting the patient fit for anesthesia. Inspite of this delay in 14 of the 15 acute cases closed reduction was possible and in 1case of non-union closed reduction was possible. An average delay of 4.5 months was seen in the cases of non-union.

In our series union was noted in 11 of the 12 acute Fractures at an union rate of 92%. This is in comparison to certain international studies in which union rates of 80-100% is noted. The rate of union is comparable to plate osteo-synthesis which in international standards is around 85-92%.

In our series of non-union 4 of the 5 cases united and 1 case in which closed reduction was done without bonegrafting is only in the third

month of follow up. Fracture site compression and static locking if achieved the fracture non-union have been found to unite well. Ours being a small study may not reflect the true picture in management of fracture non-union of humeral diaphyseal fractures.

The average time in union of acute fractures was found to be at around 14.5 weeks. Other studies have shown a slightly quicker rate of union at about 12.5 weeks. Probably the delay in the time interval of surgery contributed to the slight delay in the time of fracture union.

Post –op nerve palsy did not occur in any of the cases, in which closed reduction was done. In fact one of the cases which had a pre-op Radial N palsy recovered fully in 2 months time with an additional nerve stimulation and a Dynamic cock up splint. 1 case of the open reduction which was opened by the anterolateral approach developed post-op Radial N palsy, it recovered fully in 3 months time with the same above modality of treatment.

None of our cases developed post-op infection and in this aspect of Radial N protection from iatrogenic injury and very less chances of infection definitely Interlocking Nail scores over Plate-osteosynthesis.

Of the 12 cases of acute fractures of humerus treated, 8 cases attained near range of movements in shoulder compared to the opposite side, 2 of the acute fracture cases who did not have full range of shoulder movement were operated 45 days after injury due to anasthetic

complications.1 case of acute fracture did not follow the post-op physiotherapy protocol that was advised.

Of the cases of non-union 1 case achieved full range of movement, 1 case is in 3 months follow up and has nearly 80% of movements on the normal side.

No case of shoulder instability was noted. 1 case of acute fracture which went in for non-union had moderate level of pain in the shoulder.

1 patient who had a comminuted proximal ulnar fracture that was treated conservatively had moderate restriction of movements in the elbow. The delay in the interval between surgery and injury may also have contributed for the loss of range of movements in shoulder, care must be taken to suture the rotator cuff properly. It has been observed that **proper aggressive post-operative physiotherapy protocol if followed full normal range of movements of shoulder is regained.** Also care must be taken to flush the surface of nail with the bone to prevent the impingement at the shoulder joint. In our series only 1 case which happened to be the first of the series had significant proximal protrusion of nail.

All fractures treated with nailing had proper alignment of the fracture site, while functional bracing according to studies have cosmetically unacceptable angulation in nearly 12-15% of cases. The

ratio was more in co-aptation splinting. As the nail is used as an internal splint there is no evidence of mal alignment of fractures.

Difficulty was encountered in finding the entry point for few of the obese patients. Fracture site splintering occurred in 3 cases, but the splinters had completely united in due course of time. Difficulty was noticed in Distal locking due to the sloping nature of the distal humerus and most of the time locking could not be achieved with the distal jig. Image intensifier is a must for entry point insertion, fracture reduction and distal locking which can definitely reduce the operating time and can give better functional results.

CONCLUSION

- **Inter locking nailing of humerus is a safe and good alternative to treat acute fractures and non – union of the diaphysis.**
- **The union rate is very good and comparable to that of Plate-osteosynthesis.**
- **The infection rate is very minimal**
- **Intraoperative blood loss is less.**
- **Chances of iatrogenic Radial N injury is less**
- **Lesser malalignment.**
- **Rotationally stable and cosmetically appealing.**
- **Shoulder stiffness can be prevented with early fixation and proper rehabilitation protocol.**

PROFORMA

NAME**:**

AGE:

SEX:

ADDRESS**:**

IP NO :

DOA:

DOS:

DOD:

Mode of injury:

Side of injury: R/L

Open/Closed fracture

AO classification

Associated injuries

Neurovascular injuries

INVESTIGATIONS

- Plain X Ray AP and Lateral views
- Blood Hb/BT/CT/Urea/Sugar/Grouping &typing
- Chest X Ray
- ECG

INITIAL MANAGEMENT:

- Improvement of general condition
- Closed reduction / U slab
- Wound debridement

DETAILS OF SURGERY

- Interval between surgery and injury
- Preoperative range of movements
- Patient position
- Anesthesia
- Duration of surgery
- Entry portal
- Fracture reduction
- Length and diameter of nail
- Proximal and distal locking details
- Blood loss

COMPLICATIONS

- Per operative
- Early post operative
- Late post operative

CLINICAL ASSESSMENT IN FOLLOWUP PERIOD

Sepsis/shoulder pain/shoulder and elbow range of movements

RADIOLOGICAL ASSESSMENT DURING FOLLOWUP PERIOD

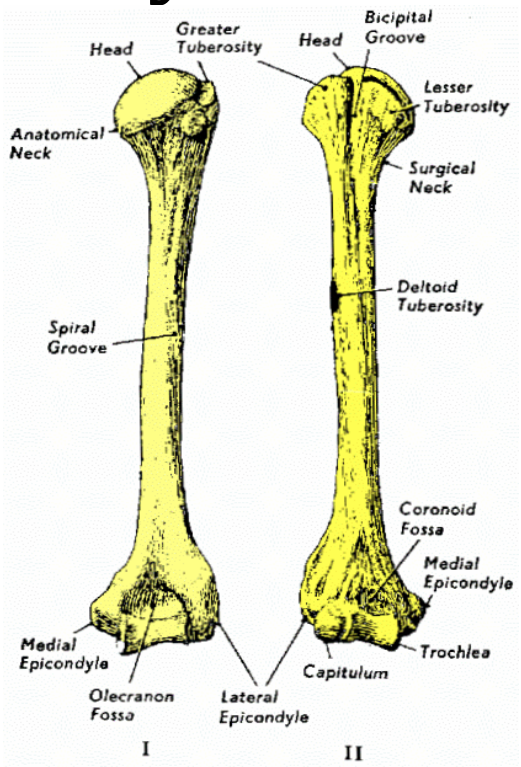
Callus appearance/union time/ Delayed union/ non-union

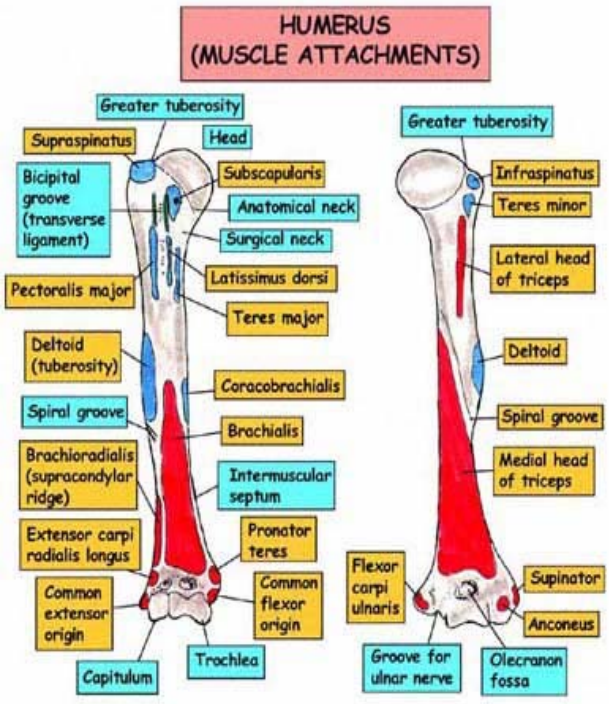
DETAILS OF SECONDARY PROCEDURE

FUNCTIONAL OUTCOME

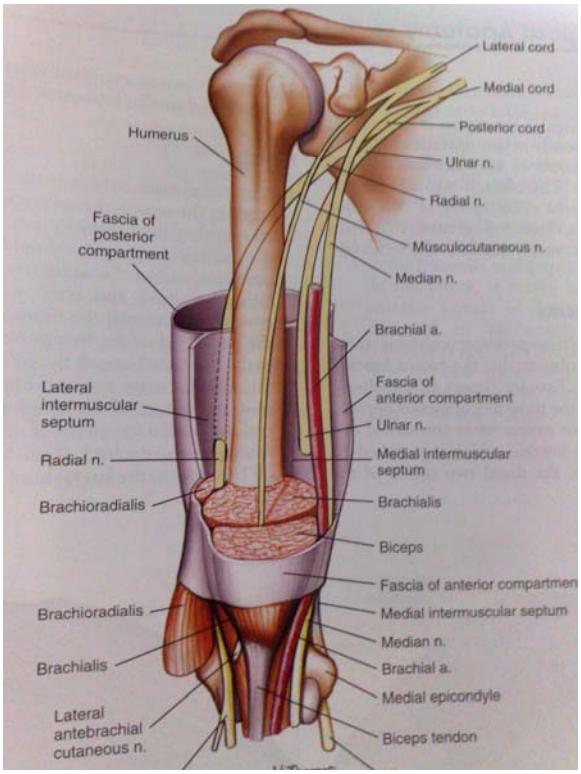
Excellent/good/fair/poor

Anatomy of humerus





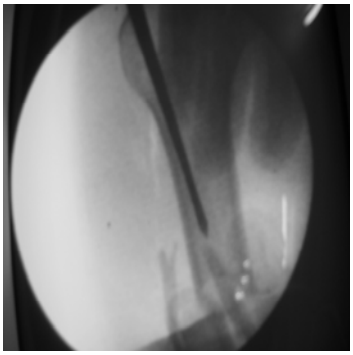
Neurovascular relations



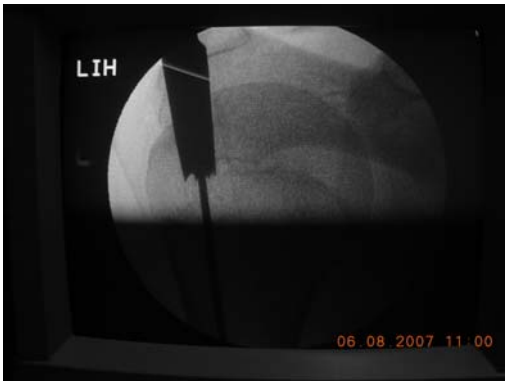
Radial nerve course

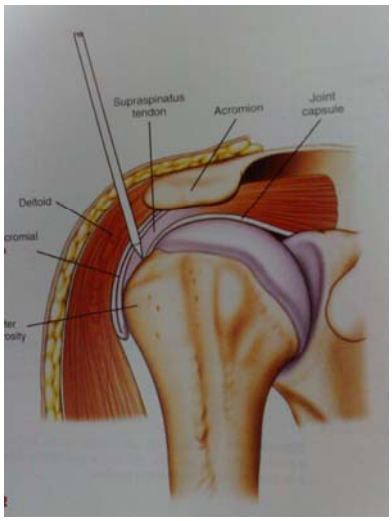
Entry point

Entry made with K-wire



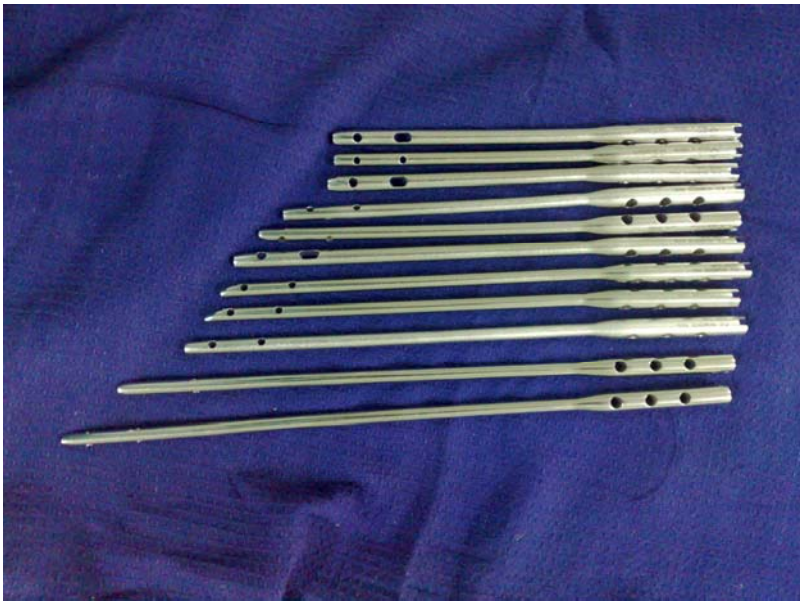
Entry point reamer insertion





Guide wire insertion

IMPLANT DESIGN



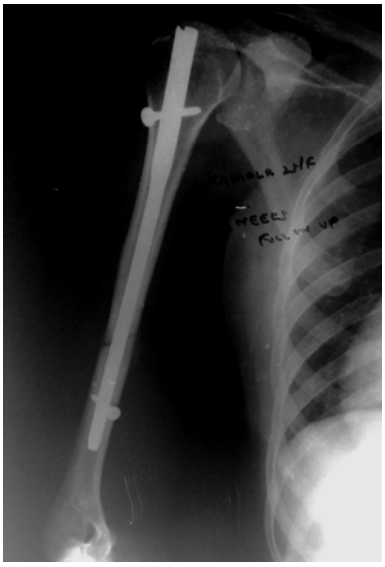
INSTRUMENTATION

Case-I

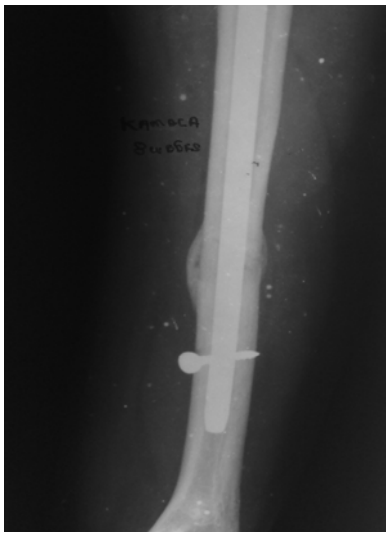
PRE-OP

IMMED. POST-OP

4 WEEKS POST-OP



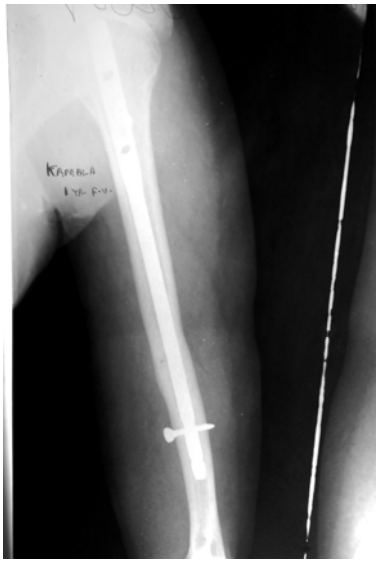
8 WEEKS POST-OP



16 WEEKS POST-OP

24 WEEKS POST-OP

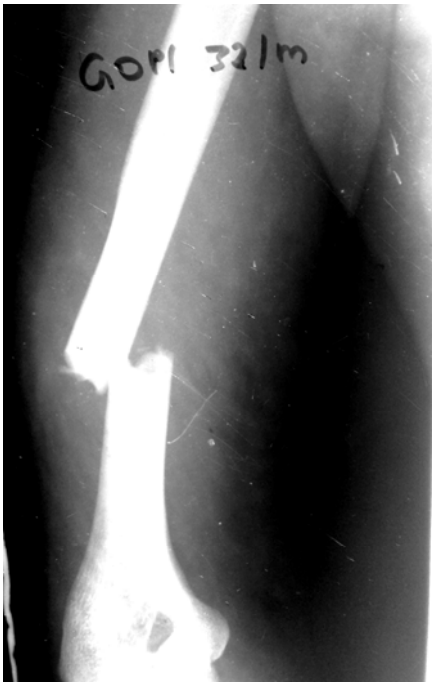
1 YEAR FOLLOW-UP



18 MONTHS FOLLOW-UP

RANGE OF MOVEMENTS

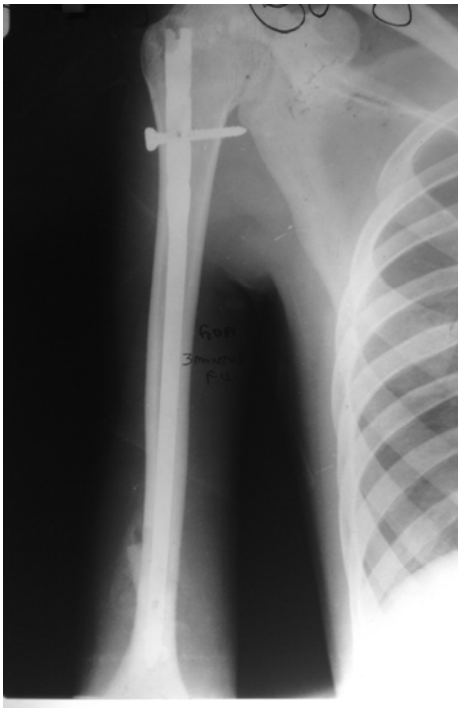
Case-II



Pre-op

Immed. Post-op

4 weeks post-op



12 weeks post-op

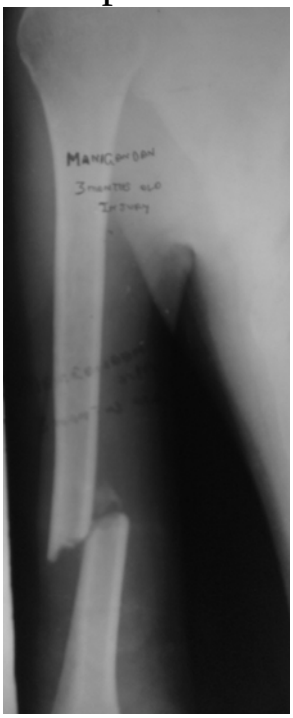
6 months post-op

12 months post-op

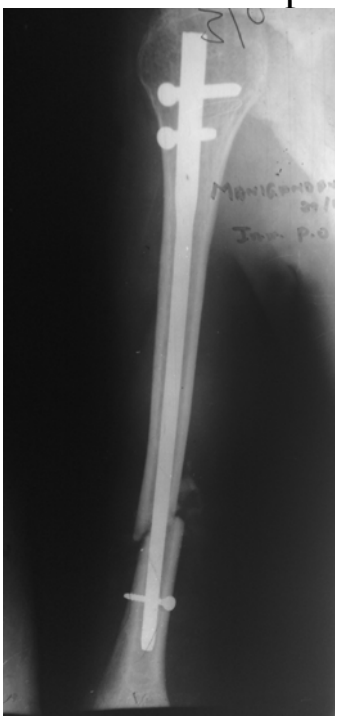
RANGE OF MOVEMENTS

CASE III

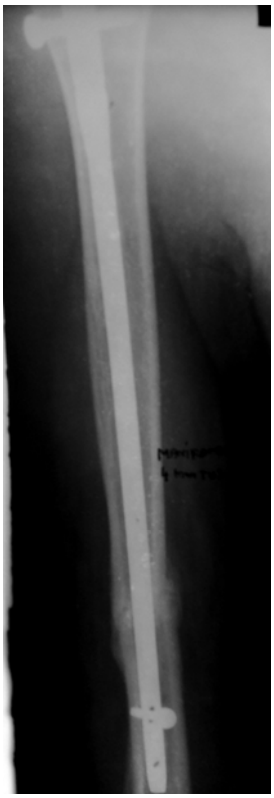
Pre-op



Immed. Post-op



16weeks PO



24 weeks PO

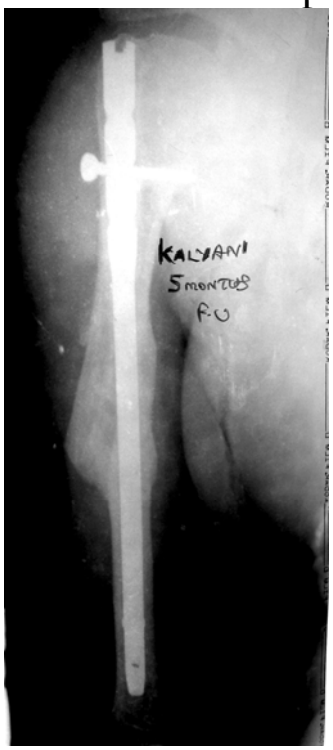
1 year follow-up

Case - IV

Pre-op

Immed. Post-op

5 months Post-op



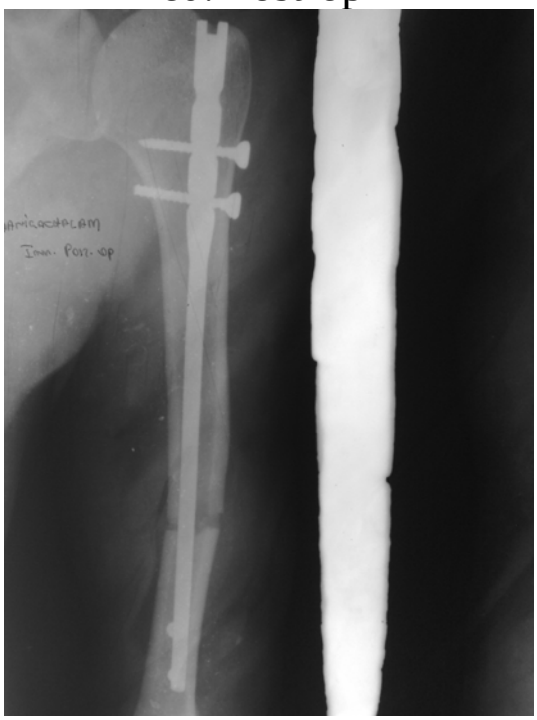
6 months Post-op

RANGE OF MOVEMENTS

CASE - V

Pre-op

Immed. Post-op



4 weeks post-op

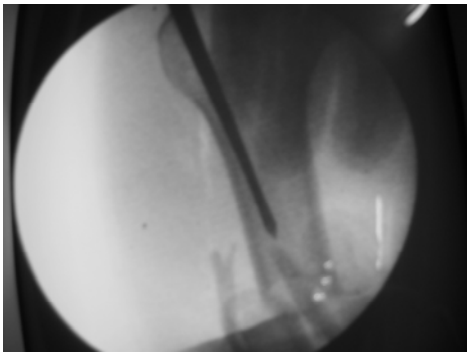
6 weeks post-op
(Distal screw broken)

8 weeks post-op

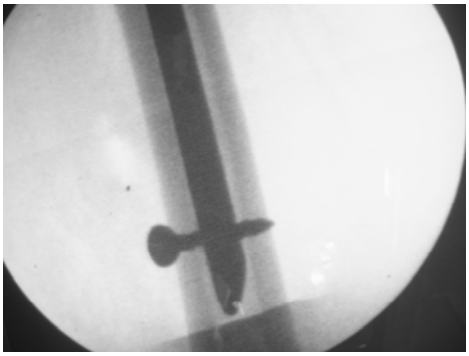
INTRA-OP PICTURES

ANAESTHESIA

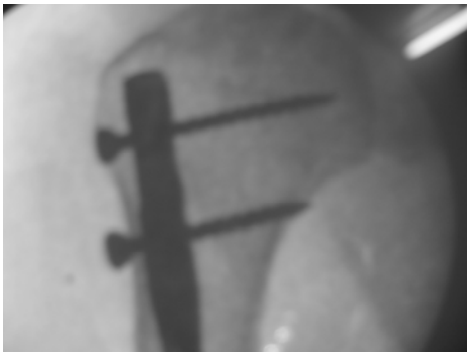
POSITIONING



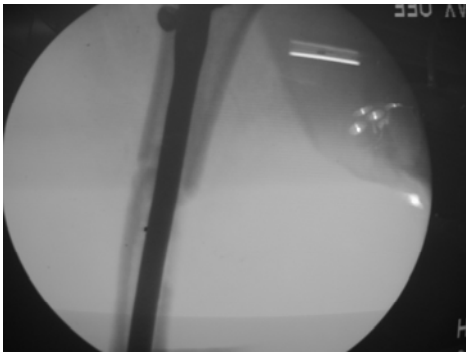
ENTRY POINT



DISTAL LOCK



PROXIMAL LOCK



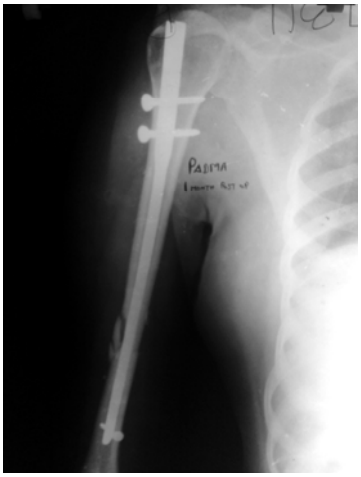
FRACTURE SITE

IMMEDIATE POST-OP ELBOW MOVEMENTS AND STABILITY

CASE - VI

PRE-OP

IMMED. POST-OP



1 MONTH POST-OP

2 MONTH POST-OP

4 MONTH POST-OP

4 MONTH POST-OP

CASE - VII

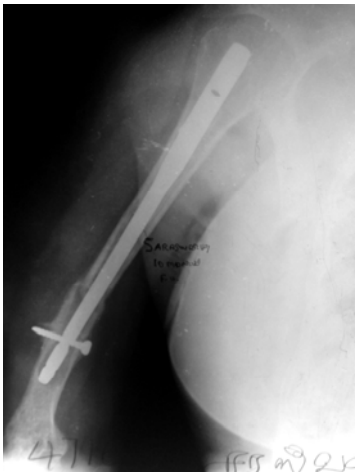
PRE-OP

IMMED. POST-OP

8 WEEKS POST-OP

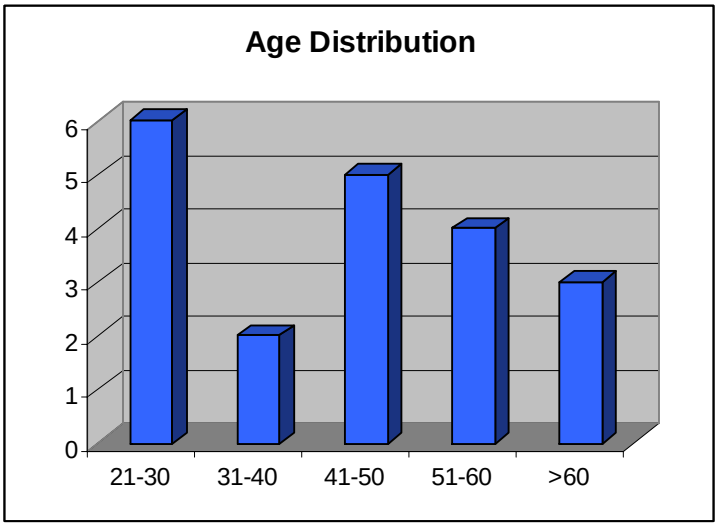
8 MONTHS POST-OP

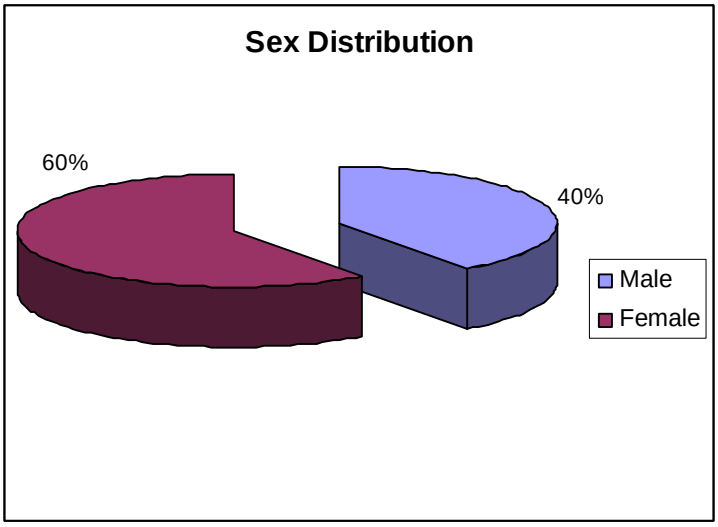
10 MONTHS POST-OP

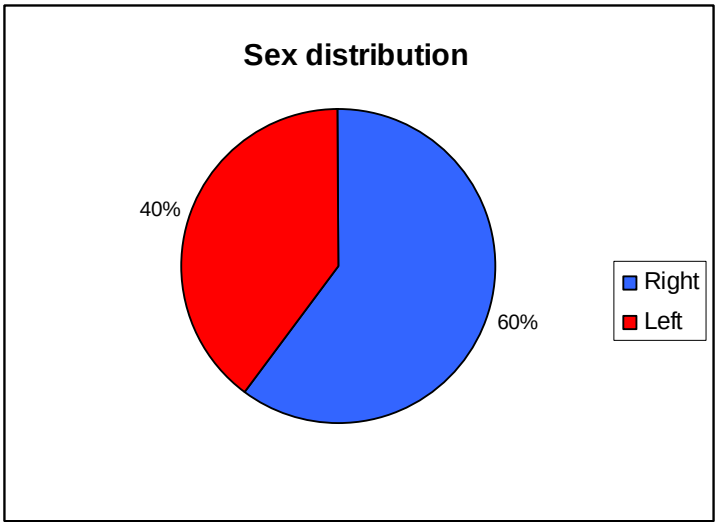


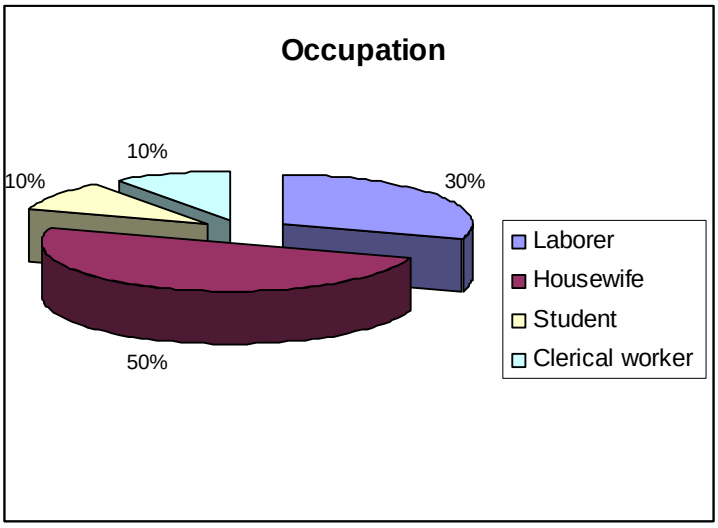
10 MONTHS POST-OP

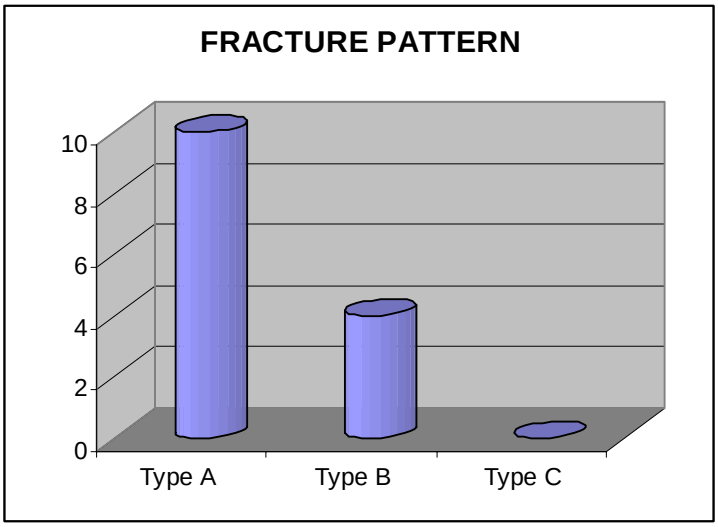
RANGE OF MOVEMENTS

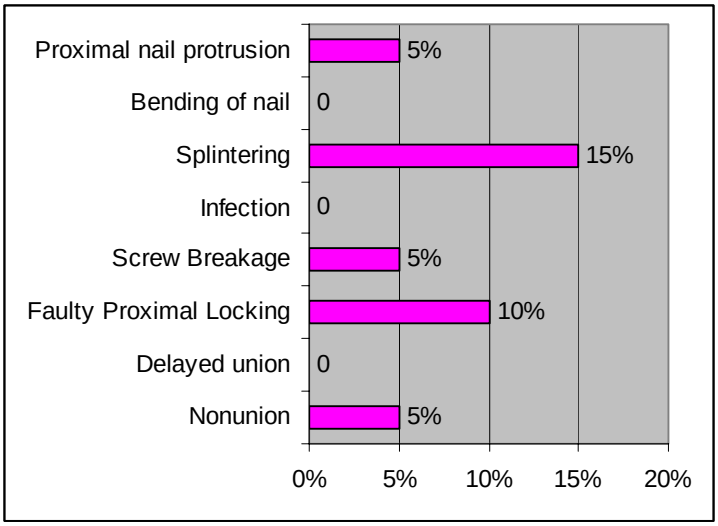

Age Distribution
6
5
4
3
2
1
0
21-30
31-40
41-50
51-60
>60


Sex Distribution
60%
40%
Male
Female


Sex distribution
40%
60%
Right
Left


Occupation
10%
10%
30%
50%
Laborer
Housewife
Student
Clerical worker


FRACTURE PATTERN
10
8
6
4
2
0
Type A
Type B
Type C


Proximal nail protrusion
5%
Bending of nail
0
Splintering
15%
Infection
0
Screw Breakage
5%
Faulty Proximal Locking
10%
Delayed union
0
Nonunion
5%
0%
5%
10%
15%
20%

MASTER CHART

S.no	Name	Age	Sex	I.P. no	Mode of injury	Injury Type	Acute/ Non-union	Associated Injuries	Interval Bet. Inj & Surgery	Reduction	Bone graft	Nail size
1	Tamilarasi	55	F	5368	FALL	Closed	Acute	# BB Leg	30 days	Closed		7*240 mm
2	Muniammal	45	F	6814	RTA	Closed	Acute	Olecranon #	45 days	Closed		7*200 mm
3	Kamala	32	F	6703	RTA	Closed	Acute	# BB Leg	8 days	Closed		7*240 mm
4	Kavitha	27	F	8272	RTA	Closed	Acute		7 days	Closed		6*220 mm
5	Saraswathy	42	F	11930	RTA	Closed	Acute		12 days	Closed		7*200 mm
6	Gopi	32	M	15229	RTA	Closed	Acute		7 days	Closed		7*260mm
7	Gopalakrishnan	30	M	16033	RTA	Grade-I open	Acute	Radial N. Injury	10 days	Closed		6*260 mm
8	Gopi	23	M	27222	RTA	Closed	Acute		8 days	Closed		7*220 mm
9	Padma	32	F	21265	RTA	Closed	Acute		15 days	Closed		6*240 mm
10	Rajasekaran	45	M	7154	RTA	Closed	Acute		50 days	Open		7*240 mm
11	Hildaesther	45	F	8515	FALL	Closed	Acute		18 days	Closed		7*240 mm
12	Kandasamy	30	M	15670	RTA	Closed	Acute	# BB Leg	12 days	Closed		7*240mm
13	Thanigachalam	50	M	15421	RTA	Closed	Acute		12 days	Closed		6*240mm
14	Kalyani	65	F	6112	FALL	Closed	Nonunion		4 mths	Open	Yes	7*200mm
15	Nagammal	58	F	7833	FALL	Closed	Nonunion		6 mths	Open	Yes	7*230mm
16	Manigandan	26	M	17643	RTA	Closed	Nonunion	Liver laceration	3 mths	Open	Yes	7*280mm
17	Padmavathy	68	F	12234	RTA	Closed	Nonunion		6 mths	Open	Yes	6*200mm
18	Noorjahan	58	F	13332	FALL	Closed	Nonunion		3 mths	Closed		7*200mm
19	Deivanai	70	F	7224	FALL	closed	Nonunion		6 mths	Open	Yes	7*240mm
20	Laxminarasiman	70	M	6104	RTA	Closed	acute		4 days	Closed		7*240mm